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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM-78-2922-3

AD A095551

ULTRA LOW LOSS OPTICAL FIBER CABLE ASSEMBLIES

R. KOPSTEIN

ITT Electro-Optical Products Division

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FEBRUARY 1981

SEMI-ANNUAL REPORT FOR PERIOD
MAY 1,1980 - NOVEMBER 30,1980

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: CORADCOM 78-2922-3

2. GOVT ACCESSION NO.: AD-A095 551

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): ULTRA LOW LOSS OPTICAL FIBER CABLE ASSEMBLIES

5. TYPE OF REPORT & PERIOD COVERED: Semiannual 1 May 80-30 Nov 80

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Robert Kopstein

8. CONTRACT OR GRANT NUMBER(s): DAAB07-78-C-2922

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
ITT Electro-Optical Products Division
7635 Plantation Road, N.W.
Roanoke, VA 24019

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 612701.H92.MA.11.20

11. CONTROLLING OFFICE NAME AND ADDRESS:
US Army Communications Research & Dev Command
ATTN: DRDCO-COM-RM-1 (Kalomiris)
Ft Monmouth, NJ 07703

12. REPORT DATE: February 1981

13. NUMBER OF PAGES: 68

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release: distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fiber optics; optical fibers; optical multifiber cable; ruggedized cable; fiber optic cable assemblies; fiber optic hermaphroditic connectors; fiber attenuation; fiber dispersion; test data on fibers; jeweled ferrule connectors; adjustable three-sphere connectors

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress toward development of ruggedized ultra low loss (<8.0 dB/km) optical fiber cable assemblies consisting of six optical fibers is reported. Effort involves investigations of fiber, cabling, and connector development on an individual as well as combined basis for meeting requirements of tactical tdm communication systems.

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20. During this reporting period final cable assemblies were fabricated, fiber and cable optimization for low temperature performance and impact survivability was completed, jacket polyurethane materials were evaluated, and connector/receptacle development work was finalized.

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1.0 INTRODUCTION

The objective of the ultra low loss optical fiber cable assemblies contract (DAAB07-78-C-2922) is to develop cable assemblies for Army tactical field data transmission at 20 Mb/s over 8 km without repeaters.

The contract effort includes the development of rugged cable, hermaphroditic cable connectors, and bulkhead receptacles which are optimized for tactical field applications.

This report covers the final cable and connector development effort, fabrication, and initial characterization of cable.

1.1 Work Planned for This Reporting Period

Work on the following tasks was planned for this reporting period:

a. Program review with ITT Cannon to discuss cable/connector interface items and overall assembly performance

b. Connector development - Modify and evaluate existing connector to reduce cable assembly losses

c. Cable design - Select cable design based on the data generated and further evaluate low temperature performance

d. Complete effort to address low temperature fiber performance as pertains to buffer coating thickness

e. Obtain additional fibers to construct cables for final cable/connector assemblies

f. Complete optical measurements on fibers and fabricate final assemblies

2.0 FINAL CABLE DESIGN

This section covers the description, construction, and evaluation of the three 1 km cable samples for the final assemblies.

2.1 Optical Fibers

The light transmitting elements of the cable are the graded-index optical fibers (Figure 2-1) consisting of a glass core (germanium, phosphorus, and boron dopants) and a glass cladding (germanium, phosphorus, and boron dopants). To preserve the mechanical strength of the glass fibers, they are coated with RTV and Hytrel® plastic buffers. These buffers protect the optical fiber as described in the following paragraphs.

The graded-index optical fibers are to meet the following specifications at 0.82-μm wavelength after proof loading at 690 N/mm^2:

a.	Fiber core	55 μm ±5 μm
b.	Fiber outside diameter (od)	125 μm ±6 μm
c.	Attenuation	<5.0 dB/km
d.	Dispersion	<2.0 ns/km
e.	Numerical aperture (NA) (90% power)	>0.14

2.1.1 Primary Buffer

A room temperature vulcanizing (RTV) silicone protective coating,

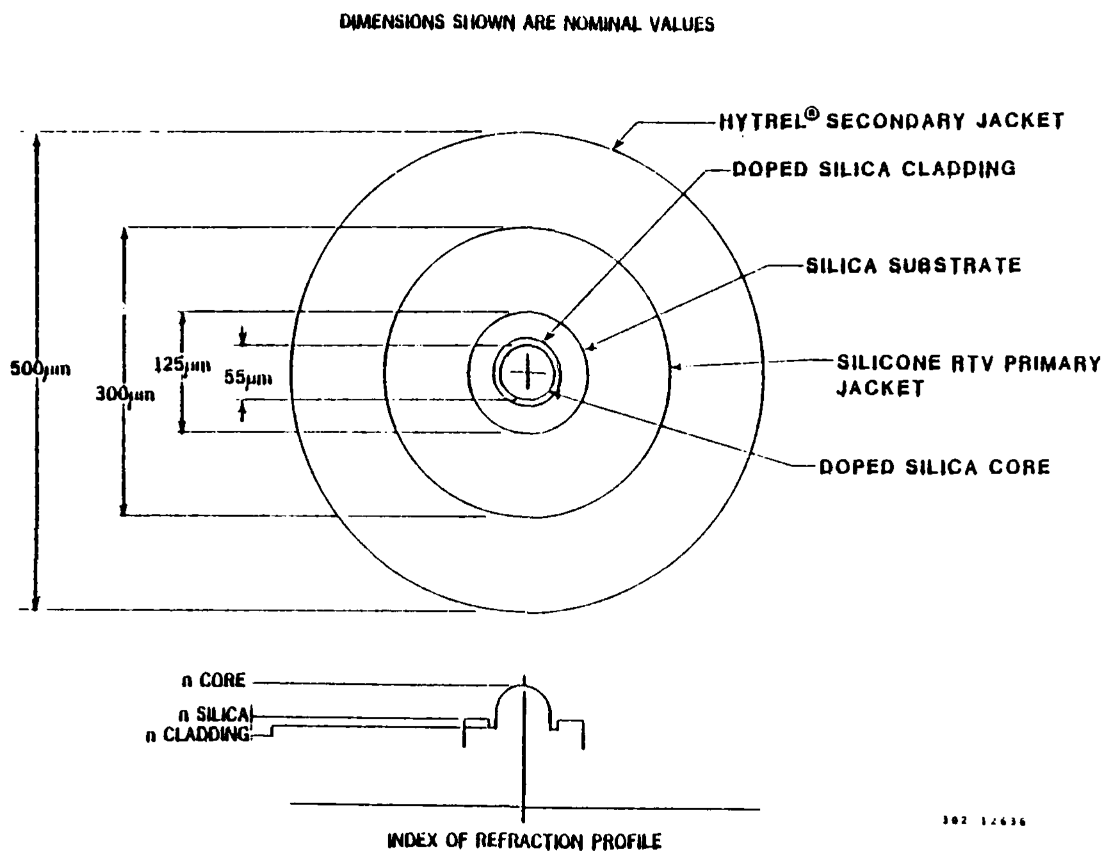

Figure 2-1. Wideband Graded Index Multimode Optical Fiber.

Dow Corning Sylgard® 184, is applied by dipcoating to a finished diameter of 300 μm immediately after drawing. This protective coating guards the fibers from any initial handling or foreign substances that may damage or reduce the quality of the product and is compatible with the buffering materials. Sylgard® 184 is used because of the ease in stripping this material.

2.1.2 Secondary Buffer

All fibers have a Hytrel® 7246 buffer layer for additional protection. The layer is tubing extruded to a finished diameter of 0.5 mm. An additional layer is pressure extruded to 0.94 mm to provide the rugged mechanical and environmental performance.

2.1.3 Center Filler

The center filler element of the cable is an impregnated 380 denier Kevlar® 49 yarn which is jacketed to 1.0 mm od with black polyurethane (Roylar® E-80). This construction provides for additional resiliency to impact loads.

2.1.4 Cable Core

The six optical fibers are helically applied around the center filler (Figure 2-2) with a 7.6 cm (3.0 in) right-hand lay.

2.1.5 Polyurethane Inner Jacket

The polyurethane inner jacket is extruded after the cabling

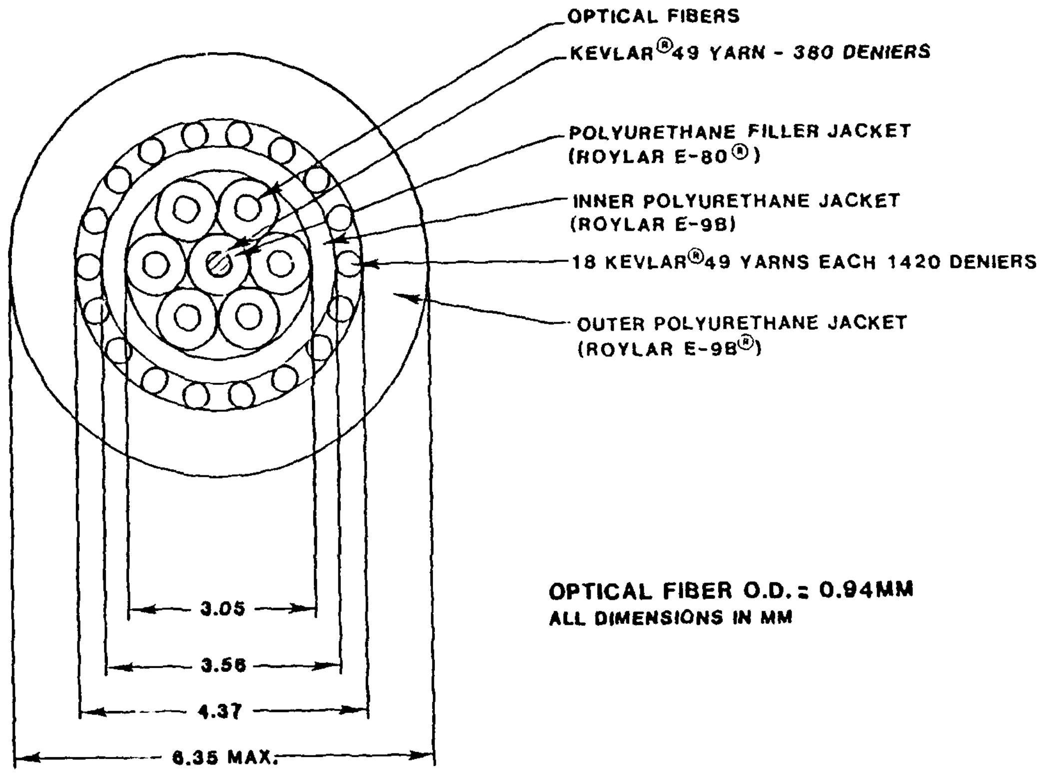

Figure 2-2. Basic Cable Design.

operation. The polyurethane used is Roylar® E9-B, a polyether based compound, manufactured by Uniroyal. It is chosen because of its extreme toughness, abrasion resistance, low temperature flexibility, resistance to hydrolysis, fungus resistance, and excellent stability to atmospheric conditions. This jacket supplies support for the fiber making up the cable core and provides a buffer layer between the fibers and Kevlar®, reducing abrasion.

2.1.6 Kevlar® Strength Members

Kevlar® 49 has been chosen as the strength member for this application because of its strength versus weight and durability. A total of 18 yarns (1420 denier) is applied helically with a 10.1 cm (4.0 in) lay length. The lay length was selected to be greater than that of the fibers to ensure that the Kevlar® absorbs the tensile load. The strength member will provide 181.8 kg (400 lb) tensile strength at 1% elongation. One percent elongation is the 0.689 MPa (100 kpsi) fiber proof test level.

2.1.7 Polyurethane Outer Jacket

The polyurethane outer jacket is tubing extruded after the Kevlar® strength members are applied to a finished diameter of 6.15 mm ±0.2 mm (see Figure 2-2). The Roylar® E-9B polyurethane, manufactured by Uniroyal, is a polyether based compound.

2.2 Optical Evaluation

The attenuation, dispersion, and 90% power NA were measured on the three 1 km cables using the measurement techniques indicated in Appendix A.

2.2.1 Attenuation Measurement Results

The three cable samples were fabricated in a 3176 m continuous length and attenuation measurements were completed prior to cutting into 1 km lengths. The attenuation on the fibers before cabling (Table 2-1) averaged 3.53 dB/km and 3.33 dB/km after cabling indicating a 0.20 dB/km reduction. This consistent and small reduction in attenuation after cabling can be attributed to initial high spool tensions and pressure points from each layer winding.

The attenuation on each fiber in the 3176 m finished cable was measured at five wavelengths (0.82, 0.85, 1.06, 1.10, and 1.20 μm). The average attenuation at 0.82 μm wavelength was 3.76 dB/km and at 1.20 μm wavelength the attenuation was 1.15 dB/km. The statement of work on this contract does not require measurements at wavelengths greater than 1.05 μm, but since CORADCOM demonstrates interest in long wavelength transmission, ITT EOPD evaluated the cables at 1.06, 1.10, and 1.20 μm as indicated in Table 2-2.

Table 2-1. Cabling Loss (061780-4c-1, 3176 m).

Fiber Ident	Attenuation (dB/km) Before	After	Δ
1. Brown	3.05	2.91	-0.14
2. White	*	*	*
3. Blue	3.41	3.06	-0.35
4. Orange	3.45	3.10	-0.35
5. Slate	3.68	3.55	-0.13
6. Green	4.04	4.04	-0.00
Average	3.53	3.33	-0.20

*Attenuation measured at 0.85 μm wavelength and 0.089 injection NA. The white fiber was intentionally cabled in two pieces (1100 m and 2200 m) without splicing. Therefore, attenuation could not be measured on this fiber in the 3-km cable section.

Table 2-2. Attenuation Versus Wavelength (dB/km).

(061780-4c-1, 3176 m)

Fiber Ident	Wavelength (μm) 0.82	0.85	1.06	1.10	1.20
1. Brown	3.27	2.91	1.34	1.21	1.03
2. White	*	*	*	*	*
3. Blue	3.52	3.06	1.31	1.13	0.86
4. Orange	3.48	3.10	1.48	1.32	1.09
5. Slate	4.05	3.55	1.70	1.54	1.33
6. Green	4.48	4.04	1.92	1.73	1.44
Average	3.76	3.33	1.55	1.39	1.15

*The white fiber was intentionally cabled in two pieces (1100 m and 2200 m); attenuation measured at 0.089 injection NA. The attenuation data could not be obtained for the white fiber in the 3-km cable.

The 3176 m cable was cut into three lengths (1025, 1100, and 1018 m) and the attenuation was measured again at the five wavelengths indicated in Table 2-3. The average attenuation of the three cables after cutting was 0.39 dB/km higher at both 0.82 μm and 1.20 μm wavelengths. This higher attenuation in the shorter length cables can be attributed to high order modal losses which are depressed in the 3176 m section. After cutting the 3-km cable into three cables, two cables had one fiber each with 5.07 and 5.06 dB/km attenuation at 0.82 μm wavelength which slightly exceeds the program objective of 5.0 dB/km. The data indicates that when a cable is fabricated in a long length (3 km) the results of fiber performance may vary down the cable length.

The attenuation versus injection NA results in Table 2-4 indicate that as the injection cone angle increases beyond a certain steady state value, the high order modes become more prevalent and the attenuation increases accordingly.

While the 0.089 injection NA is substantially less than the NA of the fiber, Kaiser[1] has reported that low NA injection of similar graded index fibers results in a modal distribution closer to steady state conditions than that achieved with higher injection

---

[1] P. Kaiser. "NA-Dependent Spectral Loss Measurements of Optical Fibers," Transactions of the Inst of El and Comm Eng, Japan, March 1978.

Table 2-3. Attenuation Versus Wavelength (dB/km).*

061780-4c-1a1, 1025 m

Fiber Ident	0.82	0.85	1.06	1.10	1.20
1. Brown	3.80	3.34	1.93	1.60	1.55
2. White	4.06	3.62	2.07	1.87	2.20
3. Blue	4.94	4.41	2.42	2.25	1.90
4. Orange	4.20	3.86	2.33	2.08	1.91
5. Slate	4.31	3.88	1.82	1.42	1.49
6. Green	5.07**	4.39	2.10	1.94	1.60
Average	4.40	3.92	2.11	1.86	1.78

Wavelength (μm)

061780-4c-1a2, 1100 m

Fiber Ident	0.82	0.85	1.06	1.10	1.20
1. Brown	4.10	3.71	2.06	1.87	1.60
2. White	3.60	3.27	1.73	1.56	1.64
3. Blue	4.04	3.59	1.79	1.55	1.25
4. Orange	3.60	3.16	1.70	1.55	1.31
5. Slate	4.45	3.95	2.15	2.00	1.85
6. Green	5.06**	4.44	2.19	1.99	1.69
Average	4.14	3.69	1.94	1.75	1.56

061780-4c-1b, 1018 m

Fiber Ident	0.82	0.85	1.06	1.10	1.20
1. Brown	3.46	3.03	1.54	1.38	1.15
2. White	3.79	3.51	1.96	1.82	1.61
3. Blue	3.80	3.44	1.79	1.58	1.33
4. Orange	3.77	3.40	1.82	1.74	1.46
5. Slate	3.47	3.05	1.17	0.97	0.74
6. Green	4.75	4.03	2.02	1.68	1.43
Average	3.84	3.41	1.72	1.53	1.29

*Attenuation measured at 0.089 injection NA.
**The attenuation on the green fiber exceeds program goals of 5.0 dB/km when cut into 1-km lengths from the original 3176 m cable.

Table 2-4. Attenuation Versus Injection NA (dB/km).*

061780-4c-1a1, 1025 m	Injection NA			
Fiber Ident	0.089	0.124	0.176	0.243
1. Brown	3.80	3.84	4.21	4.19
2. White	4.06	4.13	4.42	4.51
3. Blue	4.94	4.89	5.02	4.93
4. Orange	4.20	4.26	4.47	4.59
5. Slate	4.31	4.24	4.36	4.49
6. Green**	5.07	5.11	5.08	5.00
Average	4.40	4.41	4.59	4.62
061780-4c-1a2, 1100 m				
Fiber Ident				
1. Brown	4.10	4.22	4.34	4.39
2. White	3.60	3.45	3.43	3.52
3. Blue	4.04	4.06	4.17	4.13
4. Orange	3.60	3.70	3.88	3.80
5. Slate	4.45	4.53	4.69	4.78
6. Green**	5.06	4.87	4.94	4.90
Average	4.14	4.14	4.24	4.25
061780-4c-1b, 1018 m				
Fiber Ident				
1. Brown	3.46	3.56	3.73	3.78
2. White	3.79	3.94	4.27	4.44
3. Blue	3.80	3.81	3.97	3.99
4. Orange	3.77	3.72	3.97	4.19
5. Slate	3.47	3.64	3.90	3.98
6. Green	4.75	4.55	4.53	4.62
Average	3.84	3.87	4.06	4.17

---

*Attenuation measured at 0.82 μm wavelength.
**The attenuation on the green fiber exceeds program goals of 5.0 dB/km when cut into 1-km lengths from the original 3176 m cable.

NAs. Further, the 0.089 NA is selected to avoid excess transient losses introduced by modal over-excitation in short lengths of graded index fibers. These leaky modes may be propagated through the borosilicate cladding layer.

2.2.2 Pulse Dispersion Measurement Results

The results of the pulse dispersion measurement on the three cables (1025, 1100, and 1018 m) shown in Table 2-5 indicate an average of 1.18, 1.20, and 1.45 ns/km, respectively. One fiber had a pulse dispersion value of 2.13 ns/km which exceeds the program goal of 2.0 ns/km. The data indicates that when a long fiber is cut into shorter lengths, the pulse dispersion does not remain uniform with distance. In order to consistently meet the 2.0 ns/km program objective, either the cable will be fabricated in 1 km increments or in long length cables lower dispersion fibers will be used.

2.2.3 Numerical Aperture (90% Power) Measurement Results

The 90% power NA measured on the three cable samples had an average of 0.19 as indicated in Table 2-6. The lowest value was 0.17 and the highest 0.22.

2.2.4 Fiber Dimensional Measurement Results

The results are located in Table 2-7 for the dimensional measurements for the six fibers used in the cable prior to cutting. The

Table 2-5. Pulse Dispersion (ns/km).

Fiber Ident	061780-4c-1a1 1025 m	061780-4c-1a2 1100 m	061780-4c-1b 1018 m
1. Brown	2.13*	1.22	1.67
2. White	0.62	0.75	1.41
3. Blue	0.87	0.93	1.13
4. Orange	0.88	1.31	1.10
5. Slate	0.72	1.43	1.48
6. Green	1.84	1.58	1.92
Average	1.18	1.20	1.45

*The pulse dispersion exceeds program objectives of 2.0 ns/km. The pulse dispersion may vary along the cable length, requiring better quality fibers if cabled in 3-km lengths.

Table 2-6. Numerical Aperture (90% Power).

Fiber Ident	061780-4c-1a1 1025 m	061780-4c-1a2 1100 m	061780-4c-1b 1018 m
1. Brown	0.176	0.173	0.188
2. White	0.173	0.181	0.179
3. Blue	0.193	0.189	0.194
4. Orange	0.169	0.181	0.174
5. Slate	0.205	0.182	0.196
6. Green	0.225	0.204	0.200
Average	0.190	0.185	0.189

Table 2-7. Fiber Dimensional Measurements.

(Cable 061780-4c-1, 3300 m)

	Core Diameter (μm)		Fiber Diameter (μm)	
Fiber Ident	SOP*	EOP**	SOP*	EOP**
1. Brown	52 x 53	53	124	125
2. White	51	55	127	123 x 124
3. Blue	54 x 56	52 x 53	128 x 131	126 x 129
4. Orange	51	51 x 52	121	121 x 122
5. Slate	52	53	128	128
6. Green	55 x 56	53	124 x 127	119 x 121

*Start of pull, bottom of spool.
**End of pull, top of spool.

fiber core and overall diameter are both within program specifications.

2.2.5 Cable Low Temperature Attenuation Performance

The statement of work on this contract does not require low temperature (-55°C) attenuation measurements on the cables prior to the final cable assemblies, but since CORADCOM demonstrates interest in improving low temperature performance, ITT EOPD monitored attenuation versus temperature on the three cable samples. The average attenuation increase on the three cables (see Table 2-8) at -40°C was 0.93 dB/km and the highest increase was 2.75 dB/km. At -55°C the results became very erratic with 0.61 dB/km to greater than 26.2 dB/km changes. Further cable sample evaluations indicate that these results are attributed to the polyurethane jacket material. The modulus of the Roylar® E-9B polyurethane increases rapidly below -40°C causing high induced fiber stress and microbend losses. Samples evaluated with Roylar® E-80 polyurethane have significantly better performance at -55°C. Reasons for the dramatic improved performance of the slate fiber in all three cables remain illusive. Investigations into these problems are continuing on internal R&D efforts.

Table 2-8. Cable Low Temperature Performance.

	Attenuation Increase (dB/km)	
061780-4c-1a1, 1025 m	**-40°C**	**-55°C**
Fiber Ident		
1. Brown	1.35	>23.50
2. White	2.75	>25.80
3. Blue	0.37	7.30
4. Orange	0.92	13.25
5. Slate	0.30	2.23
6. Green	0.62	8.82
Average	1.05	>13.48
061780-4c-1a2, 1100 m		
Fiber Ident		
1. Brown	1.45	>26.20
2. White	1.04	>23.90
3. Blue	-0.42	3.68
4. Orange	0.78	9.01
5. Slate	0.05	0.87
6. Green	1.00	15.76
Average	0.65	>13.24
061780-4c-1b, 1018 m		
Fiber Ident		
1. Brown	2.14	>25.10
2. White	1.76	10.34
3. Blue	0.49	5.11
4. Orange	0.83	10.15
5. Slate	0.13	0.61
6. Green	1.27	15.34
Average	1.10	>11.11

3.0 FIBER AND CABLE OPTIMIZATION

This section examines the fiber low temperature performance versus fiber buffer diameter, jacket material evaluation, and fiber impact resistance.

3.1 Fiber Low Temperature Attenuation Performance

A selection of fibers with diameters from 0.5 mm (0.020 in) to 1.14 mm (0.045 in) was evaluated at +10°C temperature intervals down to -65°C with constant attenuation monitoring. The attenuation data in Figures 3-1 and 3-2 indicates that the low temperature fiber performance is excellent with Hytrel® buffer diameters to 0.99 m (0.039 in), but a drastic increase in attenuation starts to occur with fibers 1.00 mm (0.040 in) in diameter or larger. The data also shows that fiber buffer diameters of 0.99 mm or less have a straight line curve to -65°C, but larger diameter fibers have a high attenuation increase point starting at approximately -35°C.

3.2 Recommendations From Fiber Optimization

The results of the low temperature attenuation testing on fibers indicate that in order to achieve optimum attenuation performance at low temperature (-55°C), the buffered fiber diameter must be 0.94 mm (0.037 in) or less to allow for manufacturing tolerances and always must remain below the knee in the curve shown in Figure 3-2. This reduction in fiber buffer diameter will result in reduced impact survivability.

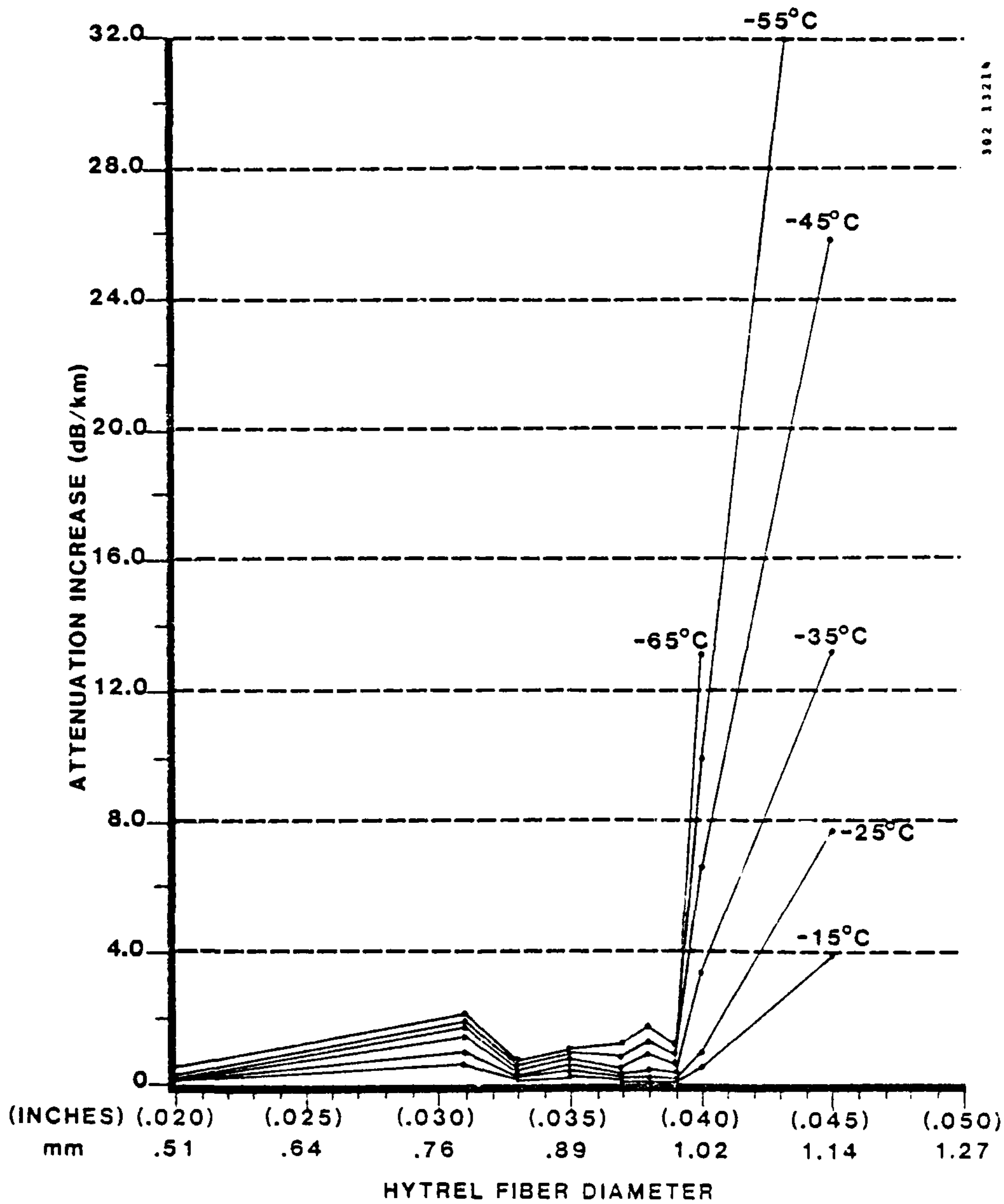

Figure 3-1. Low Temperature Attenuation Versus Fiber Diameter of Standard ITT Fibers (First Sample).

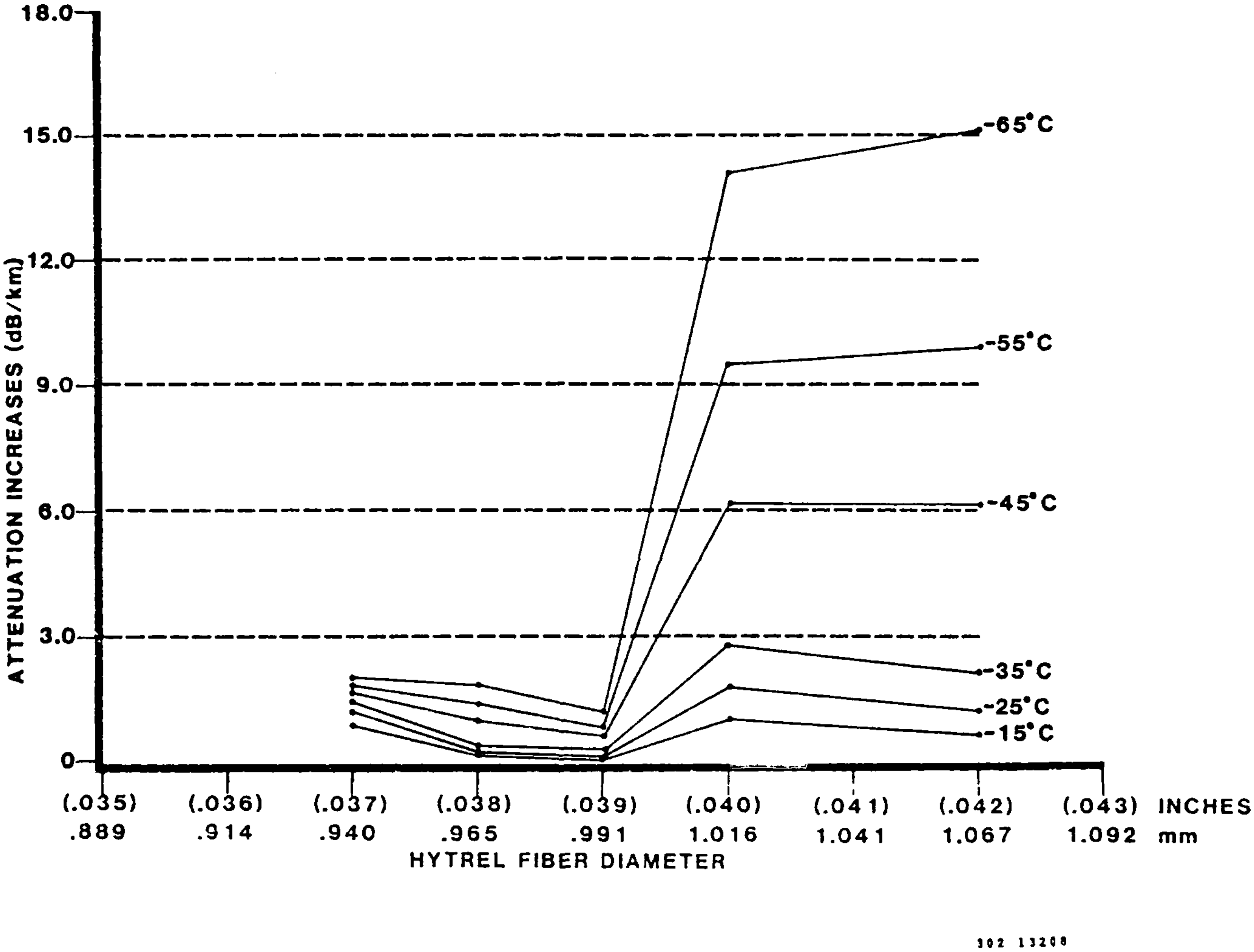

Figure 3-2. Low Temperature Attenuation Versus Fiber Diameter of Standard ITT Fibers (Second Sample).

3.3 Fiber Impact Survivability

A cable sample fabricated to the requirements of ultra low loss design 3 with 0.94 mm (0.037 in) diameter fibers was evaluated at various impact levels from 3.4 N•m to 6.0 N•m (2.5 to 4.5 ft•lb). The results shown in Figure 3-3 indicate that the fiber survivability is greatly reduced at levels greater than 4.0 N•m (3.0 ft•lb). The data shows that at 3.4 N•m the cable withstands 1300 impact cycles without any fiber failures.

3.4 Recommendations From Impact Testing

Based on the data collected for ultra low loss design 3, ITT EOPD recommends that the fiber diameter for the final cable assemblies be 0.94 mm ±0.05 mm (0.037 in ±0.002 in) and that the program impact load levels be established at 3.73 N•m (2.75 ft•lb). This will provide for optimum impact resistance while maintaining excellent low temperature attenuation performance for the ultra low loss cable assemblies.

3.5 Polyurethane Jacket Evaluation

The three 1 km cables and a 300 m length of cable for bulkhead receptacle terminations were processed through the cabling operation and stopped because of a Roylar® E-9B polyurethane low temperature problem. This problem resulted in circumferential cracks around the jacket while the cable was subjected to bend testing around a sheave at low temperature, indicating brittleness at -54°C. A sample cable was fabricated and mechanical evaluations

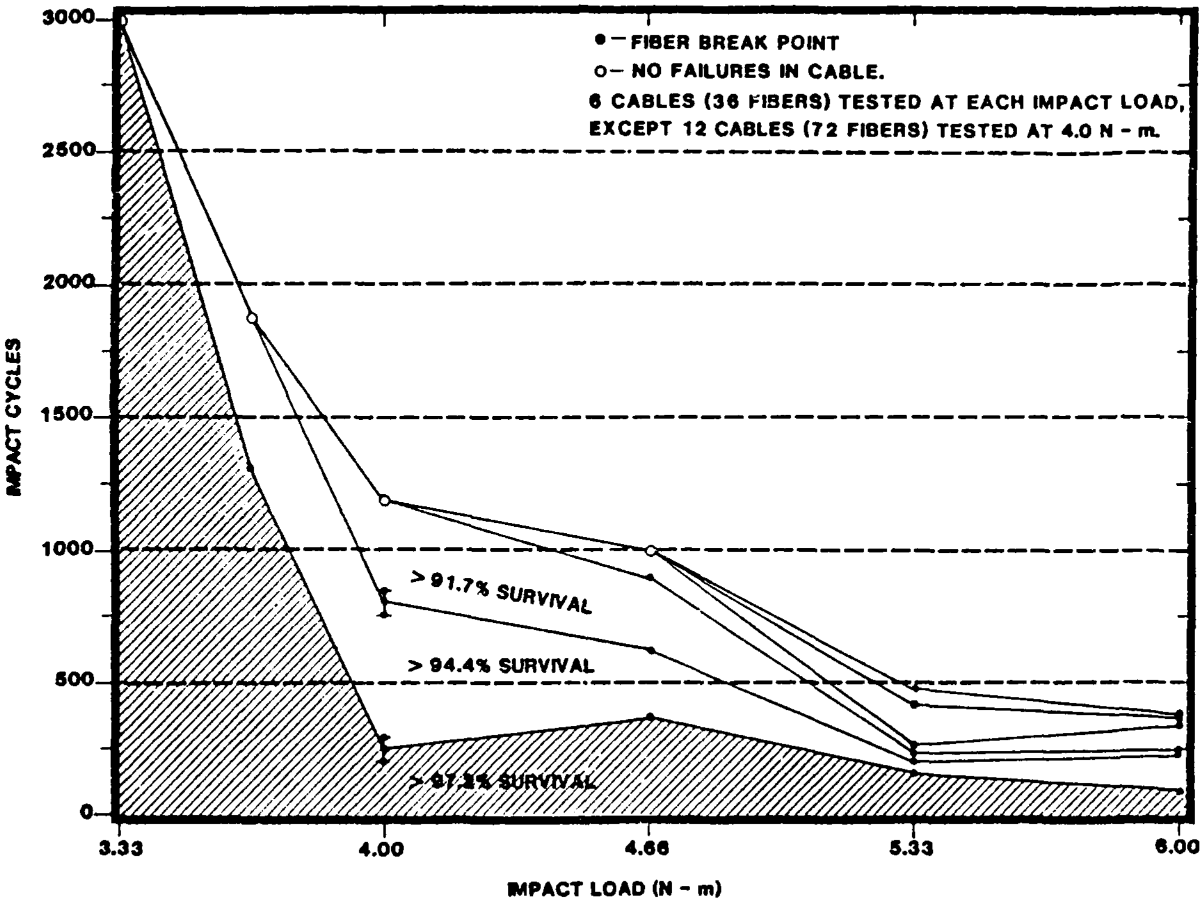

Figure 3-3. Impact Test (Room Temperature) Ultra Low Loss Cable Design 3 With 0.94 mm (0.037 in) Fibers.

conducted to determine if the new Roylar® E-9BE polyurethane was acceptable. Uniroyal made a formulation change on the grade of polyurethane and indicated that there would be no performance variation from previous batches. In fact, the samples ITT EOPD evaluated indicated a low temperature brittleness with severe jacket cracking. During this time frame, the polyurethane manufacturing facilities and all rights were sold by Uniroyal to B.F. Goodrich.

The E-9BE polyurethane and formulation were evaluated by B.F. Goodrich at the company's technical center; it was discovered that the monomer was changed to improve processing. This change caused low temperature crystallization to develop in the product initiating the cable cracking. B.F. Goodrich has located a batch of E-9B in one of its facilities that was manufactured to the previous formulation and shipped ITT EOPD a sample for evaluation. Also, B.F. Goodrich has sent ITT EOPD a sample of a modified E-9B formulation fabricated in its technical center. The previous E-9B formulations were run at the B.F. Goodrich facilities in mid-July with results shown in Table 3-1.

The results of the two polyurethane E-9B formulations tested at -54°C in accordance with MIL-C-13777F for bend testing are as follows:

a. Sample 1 (old Uniroyal formulation) - No failures

Table 3-1. Gehman Low-Temperature Torsion Test Comparison.

Compound	Lot No.	Modulus of Rigidity (psi)			Melt Index
		Room Temp.	-40°C	-50°C	190°C/8700g
Roylar E9-B	5345 300 GZ	1386	21,000	50,000	26.9
E9-B	5325 800 GZ	1475	19,000	46,000	28.0
E9-B	5345000	1631	19,000	40,000	30.6
E9-B	5367 900 GZ	1691	17,500	42,000	37.8
E9-BE	5410 800 GZ	1629	35,000	74,000	21.1
Estane 4038	9000-06	1486	25,000	60,000	55.8
4035	5902-05	903	14,500	48,000	38.0
4028	5900-02	1156	18,000	45,000	41.5
4022	9000-20	1732	40,000	74,000	33.1
Roylar E-80-NL	5368 000	647	3,800	32,300	24.6

b. Sample 2 (modified B.F. Goodrich formulation) - Jacket cracked around the cable circumference in two locations

The cables for use in the final assemblies were fabricated using previous Uniroyal E-9B formulation that passed the bend testing requirements for this program.

When the cables were completed, a sample was subjected to impact, twist, and bend testing at -54°C in accordance with MIL-C-13777F. The samples passed the impact and bend testing, but jacket cracking developed during the twist test indicating that the material was marginal in performance.

Further investigation by B.F. Goodrich (see Table 3-1) on various batches indicated that the modulus varies considerably at -50°C causing a range of brittleness. Improvements to stabilize this material will continue at B.F. Goodrich and samples will be supplied to ITT EOPD for further evaluation.

4.0 CONNECTOR DEVELOPMENT PROGRESS

The fabrication of connector hardware was completed following the design plan (CLIN 0007/A003b) for hermaphroditic connector plug and bulkhead receptacles already submitted to CORADCOM. The complete connector hardware takes approximately 12 weeks to fabricate.

4.1 Fiber Termination

Cable termination tooling is being developed to increase yield and to reduce fabrication time. One process which is being examined is a cleave and bond operation for epoxying the fiber to the jewel. The process uses powdered epoxy which can be pressed into pellet form and preassembled into the jewel ferrule assembly. The application of heat causes the epoxy to flow and then cure. This process will save time from mixing and curing individual epoxy batches.

During the report period, ITT Cannon has completed manufacture of connector hardware for test. This includes 32 different components for 20 connectors (a total of approximately 1500 components).

ITT Cannon is planning on conducting comparative tests between the cleave/bond process and the grind/polish process currently being used. The comparison test will not interfere with the evaluation

testing, but the cleave/bond procedure promises to ease the problem of six equal length terminations.

Another process is being investigated to speed up (improve) the termination procedure. ITT Cannon developed a tool for the U.S. Navy to grind and polish bundle fibers in a Cannon FON series ferrule. ITT Cannon is experimenting with grind/polish operations on the smaller FOT ferrules used on this contract. Both processes promise to shorten termination time on multiple fiber cable connectors.

4.2 Terminate Cables With Connectors/Receptacles

The pigtail lead cables have been terminated for the characterization process. The three 1 km cable assemblies are partially terminated and will be completed shortly when new guide sleeves are fabricated. The original guide sleeves were not machined properly and allowed too much clearance causing a variation in performance during the mating operation. The range of variation was between 1 and 10 dB.

The three point crimped guide sleeves which were originally designed to align mating jewel ferrules failed to provide proper alignment in preliminary testing. The crimped area did not provide parallel support ridges for the ferrules and therefore held

one ferrule tighter than the other. To correct this problem machined guide sleeves are being manufactured.

One variation from the initial design plan is the deletion of the lockwasher from the connector plug, bulkhead receptacle design, item 18 on parts list for 111271-0003 receptacle. The reason for this is that the size needed is no longer a standard item of the lockwasher manufacturer. It is also felt that the vibration and shock levels will not loosen a properly tightened jam nut. Jam nut torque requirements will be determined and specified in a future report.

4.3 Initial Cable Assembly Bend Testing

The results of the initial cold flexure test conducted at ITT Cannon indicate that the cable flexure at -58°C did not damage the jacket of the cable. The -58°C temperature selected for this test exceeds program requirements of -54°C used in evaluating the cables. The reason ITT EOPD experienced cracking of the jacket and ITT Cannon did not is due to the effectiveness of the spring portion of the connector strain relief. The spring prevented the radical bending of the cable as it exits the connector shell.

5.0 PROGRAM REVIEW AT ITT CANNON

The program review at ITT Cannon was conducted on September 19, 1980. The connector characterization and termination of the three 1 km cable assemblies were on schedule. The cleave and polish operation of the fibers in the ferrules went smoothly. None of the fibers experienced fractures or brittleness during the termination process as reported in earlier termination trials.

6.0 WORK PLANNED FOR NEXT PERIOD

The following items will be completed or addressed during the next 6-month period:

a. Complete characterization of connector/receptacles with pigtail leads

b. Complete mechanical and environmental testing of cable assemblies

c. Supply drawings and visualization data for the connector/receptacles and cable assemblies

d. Distribute semiannual report for period May 1, 1980 to November 30, 1980

e. Complete draft of final technical report and submit to CORADCOM

f. Final program review with ITT Cannon on connector/receptacle performance and cable assembly interface

APPENDIX A

MEASUREMENT TECHNIQUES

FOR OPTICAL EVALUATION

APPENDIX A.1

OPTICAL FIBER ATTENUATION MEASUREMENT SPECIFICATION INTERIM PROCEDURE

APPLICATION	
NEXT ASSY	USED ON

REVISIONS

LTR	DESCRIPTION		DATE	APPROVED
A	SCO # 7359	JK	5/29/79	6-19-79
B	SCO # 3127	JM	4/3/80	

OPTICAL FIBER ATTENUATION

MEASUREMENT SPECIFICATION

NON-CONTROLLED
FOR REVISION AND DISTRIBUTION
ISSUED FEB 17 1981

SHEET SIZE																								
REV. LETTER																								
SHEET NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
.XX DEC ±.02 .XXX DEC ±.005 ANGLE $\pm 1/2°$

MATERIAL

CONTRACT NO.

APPROVALS

DRAWN	
CHECKED	
ENGR	6/1/79
ITT	
OTHER	

ITT ELECTRO-OPTICAL PRODUCTS DIVISION
7635 PLANTATION ROAD
ROANOKE, VIRGINIA 24019

OPTICAL FIBER ATTENUATION

MEASUREMENT SPECIFICATION

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RTVJ 211599
SCALE	REV. B	SHEET 1

SD-004 3/73 004-065

A.1-2

M 9

1.0 SCOPE:

This specification describes the equipment and procedures required for the measurement of attenuation in optical fibers. The attenuation of an optical fiber has major impact on optical fiber system design and is essential for optical fiber characterization.

2.0 REFERENCE DOCUMENTS:

2.1 DOD-STD-1678, "Fiber Optics Test Methods and Instrumentation," 30 November, 1977.

3.0 EQUIPMENT: (See Figure 1)

Light Source	(A)	American Optical Model AO653 or Oriel Tunsten Halogen with regulated power supply.
Modified Slide Projector	(B)	Kodak Model 650H
Filters	(C)	.47 to 1.09 um, Corion
Light Chopper	(D)	Princeton Applied Reserach Model 125A
Injection Lens	(E)	Variable Aperture Type Ampex Model C15-7301
PCS Fiber	(F)	ITT
Collimating Lens	(G)	
Variable F-stop	(H)	Part #Ampex Model C15-7301
Test Fiber		
Output Lens		
Detector	(J)	E G & G #SGD-444
Lock-in Amplifier	(L)	Princeton Applied Research Model 124 with Model 185 Preamp

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4.0 MATERIAL:

4.1 Masking Tape (Stock #016007)

4.2 Razor Blades (Stock #026008)

4.3 Diamond Scribe RTVA 211,586 with RT VA 211,595 refill or Majestic Tool per Exp. Dwg. #1074.

4.4 T.V. Corona Dope RTVA 211585

4.5 Magnifying Glass x5 minimum (Optional)

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RTVJ 211599
SCALE	REVISION B	SHEET 2

5.0 PROCEDURE:

5.1 Set-up

5.1.1 Check that lock-in amplifier (L) controls are set as shown in Figure 2. With input applied, adjust phase for zero output when phase changed by 90°.

5.1.2 Check that power supply (K) is set at 100V with the detector (K) reverse biased (cathode positive potential).

5.1.3 Turn on all attenuation equipment.

5.2 Graded index and step index CVD fibers.

5.2.1 (Long length) Prepare ends on each end of test fiber per specification RT-VJ-211,570 . Leave 5.0 to 7.6 cm (2.0 to 3.0") of bare fiber exposed at each end. A good reflection of room light from the fiber end is adequate to determine suitable end quality.

5.2.2 Coat the entire surface of the exposed fiber with T.V. corona dope to within 0.5 cm (0.2 in.) of each end. This strips light propagating in the substrate glass. Caution is required to avoid contacting the fiber end with the T.V. corona dope. Allow to dry.

5.2.3 Position end of pull (EOP) fiber end on 5-axis positioner P_1 in slot provided in fixture.

5.2.4 Position start of pull (SOP) fiber end in detector fixture.P_2 using alignment rods to place end in proper position. Move fixture into detector until stop reached.

5.2.5 Set the slide projector controls for white light injection. Set the valuable F-stop lens H to F2 (NA = .243). Adjust positioner P_1 for maximum throughput as indicated by the output of the lock-in amplifier L. Adjust lock-in scales as required. Adjust time constant as required to obtain steady state reading.

5.2.6 Adjust slide projector to obtain filter at desired wavelength. Adjust F-stop on lens (H) for desired NA. Record steady state value and scale from lock-in amplifier (L).

5.2.7 Repeat for additional NA's at the same wavelength.

5.2.8 Repeat for each additional wavelength required.

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5.2.9 (Short Length) Remove SOP from detector. Cut fiber approximately one meter (39.4 inches) from EOP. Prepare end at point cut on one meter section per 5.2.1 and 5.2.3.
NOTE: Extreme care should be exercised to avoid disturbing the EOP end during this step.

5.2.10 Position the new end in the detector per 5.2.4. Repeat steps 5.2.6

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT-VJ 211,599
SCALE	REVISION B	SHEET 3 of 4

5.2.10 (Cont.) through 5.2.3 as during the long length measurement per requirements.

5.3 Single Mode Fibers

5.3.1 (Long Length) Prepare ends on each end of fiber per specification RT-VJ-211,570 . Leave 10.2 to 12.7 cm (4.0 to 5.0 in.) of bare fiber at each end. The end should be inspected under 10X magnification to determine end suitability. Minor flaws are permissible on fiber edges, but a smooth, flat central region is essential.

5.3.2 Perform measurement per 5.2.2 through 5.2.10 except the short length shall be 5 m long and the new end on the short length is prepared per 5.3.1.

5.4 Plastic Clad Silica (PCS) Fiber

5.4.1 Prepare both fiber ends per specification RT-VJ-211,570 . Only ~0.5 cm (.127 in.) of bare fiber is required. No T.V. corona dope is required as light does not propagate in the plastic cladding.

5.4.2 Perform attenuation measurement per 5.2.3 through 5.2.10.

5.5 Data Reduction

Substitute lock-in amplifier readings into equation below:

$$\alpha \text{ (dB/km)} = \frac{10}{L} \log 10 \frac{V_o}{V_1} (\lambda_o, NA_o)$$

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Where, L = fiber length in km

λ_o = chosen filter wavelength

V_1 = short length voltage reading at λ_o and NA_o, multiplies by scale.

V_o = long length voltage reading also at λ_o and NA_o, multiplied by scale.

NA_o = specified TV lens NA

(V_1 and V_o are reduced by synchronous spurious signal, level for very low signal levels)

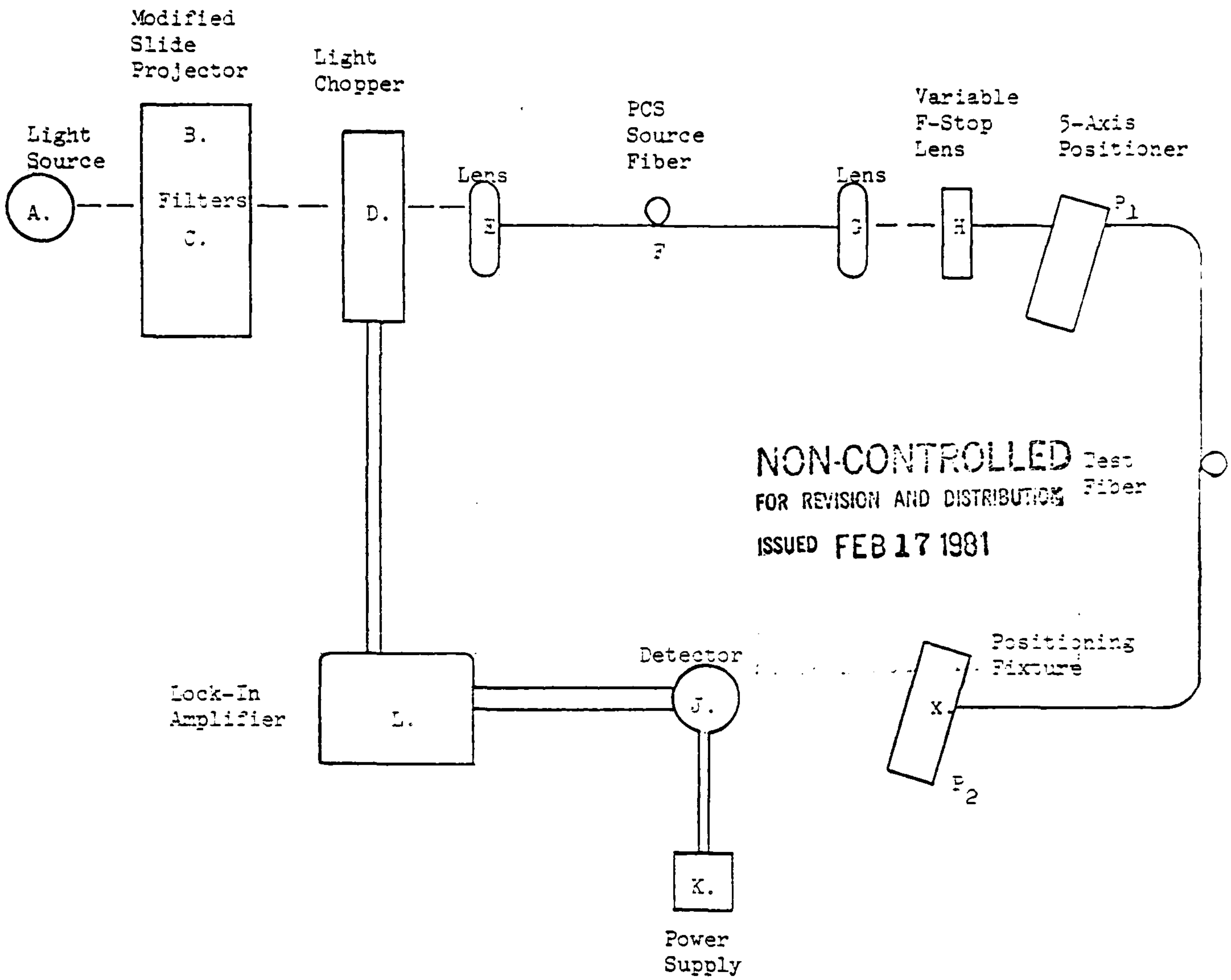
6.0 ACCEPT/REJECT:

6.1 Not needed

7.0 DELIVERY/ STORAGE:

7.1 Not needed

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT-VJ 211,599
SCALE	REVISION B	SHEET



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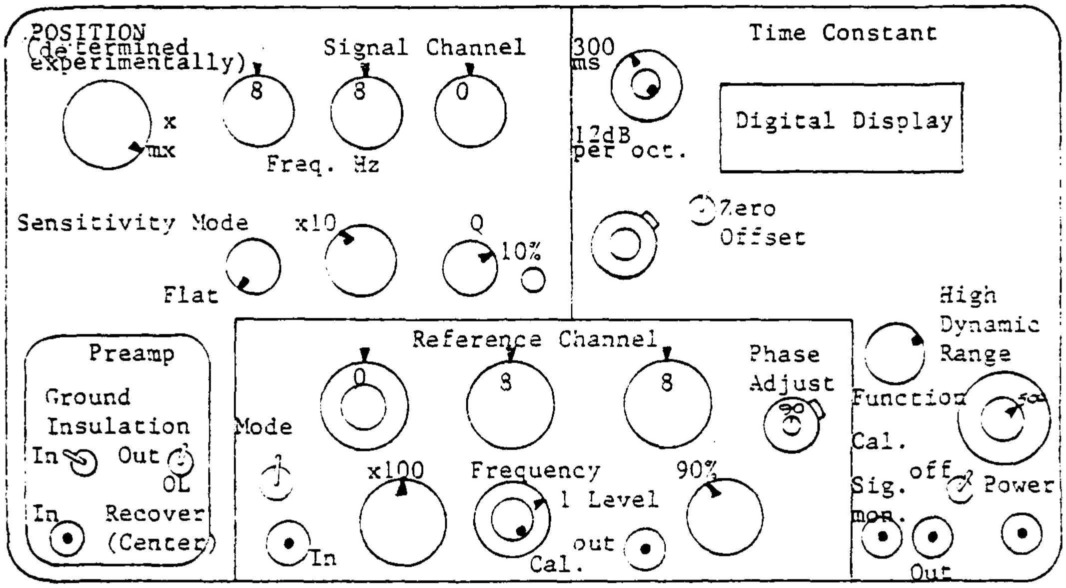
ATTENUATION MEASUREMENT APPARATUS

SIZE	CODE IDENT NO.	DRAWING NO.	
A	13567	RT-VJ 211,599	
SCALE	REVISION B	SHEET 5 of 5	

SD-005 3/73 004-098



LOCK-IN AMPLIFIER DIAL SETTINGS

FIG. 2

SIZE	CODE IDENT NO.	DRAWING NO	
A	13567	RT-VJ-211,599	
SCALE		REVISION 3	SHEET 6 of

APPENDIX A.2

OPTICAL FIBER NA AND DIMENSIONAL MEASUREMENTS

INTERIM PROCEDURE

APPLICATION	
NEXT ASSY	USED ON
	F.O.

REVISIONS					
LTR	DESCRIPTION			DATE	APPROVED
A	SCO # 7361		JK	5/29/79	6-11-79
B	SCO# 8128		SP	3/3/80	

OPTICAL FIBER N.A. AND DIMENSIONAL MEASUREMENTS

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ISSUED FEB 17 1981

SHEET SIZE																								
REV. LETTER																								
SHEET NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

.XX DEC	.XXX DEC	ANGLE
±.02	±.005	± 1/2°

MATERIAL

CONTRACT NO.

APPROVALS	
DRAWN	
CHECKED	
ENGR	6-11-79
ITT	
OTHER	

ITT ELECTRO-OPTICAL PRODUCTS DIVISION
7635 PLANTATION ROAD
ROANOKE, VIRGINIA 24019

OPTICAL FIBER N.A. AND DIMENSIONAL MEASUREMENTS

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	ET-VJ 211,601

SCALE	REV. B	SHEET 1 / 1

SD-004 3, 73 004-065

M 9

1.0 SCOPE:

The purpose of these measurements is to determine the core diameter, fiber outer diameter, and fiber numerical aperture. These parameters determine the coupling, splicing, and connectoring properties of each fiber. This specification applies to CVD fibers only.

2.0 REFERENCE DOCUMENTS:

3.1 DOD-STD-1678 "Fiber Optic Test Methods and Instrumentation." 30 November 1977.

3.0 EQUIPMENT:

Quantity	Description	Nomenclature for Diagram
1	American Optical Model No. 651T Microscope Illuminator or Oriel Tunsten Halogen with Regulated Power Supply	MI
1	25 mm dia 25 mm focal length lens	L
1	Corion SS-5300-1 1" dia 530 nm ± 50 nm Band Pass filter	F
1	Fiber Stands	FS
2	Three Axis Positioners	P1, P2
1	Flat White Screen	S
1	American Optical Microphotographic Camera Part No. A0682G	PM
1	Diamond Scribe RT VA 211,586 with RT VA 211,595 refill or Majestic Tool per Exp. Dwg. #1074	
1	0-125 mm Vernier Dial Caliper	
1	0-6" Vernier Dial Caliper	

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4.0 MATERIAL:

Description	Stock room number or Manufacturer
Razor Blades	026-008
T.V. Corona Dope	RT VA 211, 585
Film	Polaroid Type 107

5.0 PROCEDURE:

5.1 Numerical Aperture Measurement Procedure

5.1.1 Remove one meter of fiber from the end of pull (marked EOP). Make an end on both ends of the fiber leaving approximately 7.6 cm (3.0") of

272

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT-VJ 211,601
SCALE	REVISION B	SHEET 2 of 6

5.1.1 (Cont) bare fiber exposed. Use the procedure of Specification (RT VJ 211,570). Visual confirmation of room light reflection from the entire end face is adequate to assure a suitable end. Clean the end by touching masking tape to it.

5.1.1.1 Coat the entire surface of the exposed fiber with T.V. corona dope to within 0.5 cm (0.2 in.) of each end. This strips light propagating in the substrate glass. Caution is required to avoid contact the fiber end with the T.V. corona dope. Allow to dry.

5.1.2 Place the fiber end on the five axis positioner, P1. Inject the fiber with white light at an injection N.A. of 0.466. Position the fiber to maximize optical throughput.

5.1.3 Place the other end of the fiber on axis positioner, P2.

5.1.4 Place the screen so that it is 5 cm away from the end of the fiber.

5.1.5 Turn off the room lights and measure the spot diameter, d_s, in millimeters.

5.1.6 Record the spot diameter in millimeters.

5.1.7 Calculate the numerical aperature (N.A.) per N.A.=sin $(\tan^{-1} d$

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5.2 Fiber Dimensional Measurements

5.2.1 Remove 1 meter of fiber from the fiber end to be measured and make an end on each end leaving 6.3 mm (1/4") bare fiber on each end. Use the procedure of Specification (RT VJ 211,570). Visual confirmation of room light reflection is satisfactory to assure adequate end quality in the source end. For the end at the microscope one must examine the end with the viewing port of the microscope.

5.2.2 Place one end of the fiber in the 5-axis positioner. Adjust the positioner to maximize the light leaving the fiber, determined by viewing the other fiber end.

5.2.3 Place the other fiber end on the three axis positioner in front of the microscope objective.

5.2.4 Place the flat white of the camera assembly and adjust the three axis positioners so that an image forms on the screen and in front of the camera input lens.

5.2.5 Flip the lever on the back side of the camera assembly so that the viewing port may be used. With the viewing port focus the image of the fiber onto the cross mark reticle appearing in the viewing port. When the image is focussed a black dot will be visable at the center of the fiber core.

5.2.6 Place the .53 micron filter in the source optics to filter the light entering the fiber.

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT VJ 211,601

SCALE	REVISION 3	SHEET 3 of 4

5.2.7 Adjust the aperature control on the lens in front of the 5-axis positioner to the setting required to obtain a clear picture of the fiber. Turn off all room lights. Push the shutter button. Wait the appropiate exposure time, then push the shutter button a second time. This closes the shutter.

5.2.8 Pull the white paper tab at the back of the photomicroscope. This removes the film and initiates the developement process. Wait 15 seconds and pull off the developer layer.

5.2.9 Hard coat the film with the sponge provided in the film pack.

5.2.10 (Initial Fiber Evaluation Only) Repeat paragraphs 5.2.7 thru 5.2.9 on the same piece of fiber and on the same fiber end. This photograph is sent to the responsible fiber fabrication Supervisor.

5.2.11 Measure the diameter of the core at the widest point with the 0-6 inch Vernier Dial Caliper. Divide this distance by the magnification factor provided. This is the major axis diameter in microns. Record this number on the data sheet.

5.2.12 Repeat 5.2.11 for the minimum diameter of the core. If this number is not the same as in 5.2.5 record this number next to the number 5.2.5 in the format AAxBB. If the core is neither circular nor elliptical record the maximum diameters as for the elliptical case and record the general fiber core shape in the section marked"REMARKS".

5.2.13 Measure the outer of the fiber at the widest point with the 0-6 inch Vernia Dial Caliper. Divide this distance by the magnification factor provided. This is the major axis diameter in microns. Record this number on the data sheet.

5.2.14 Repeat 5.2.13 for the minimum outer diameter of the fiber. If this number is not the same as in 5.2.13 record this number next to the number of 5.2.13 in the format AAxBB. If the core is neither circular nor elliptical record the maximum and minumum diameters as for the elliptical case and record the general fiber core shape in the section marked"REMARKS".

6.0 ACCEPT/REJECT:

6.1 Not applicable.

7.0 DELIVERY/STORAGE:

7.1 Not applicable.

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SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT VJ 211,601
SCALE	REVISION 3	SHEET 4 of 4

APPENDIX A.3

FIBER PULSE DISPERSION MEASUREMENT AT 0.9 μm INTERIM PROCEDURE

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
	F.O.	A	SCO # 7360 JK	5/29/79	6-14-79

FIBER PULSE DISPERSION

MEASUREMENT AT 0.9 um

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ISSUED FEB 17 1981

SHEET SIZE																								
REV. LETTER																								
SHEET NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

.XX DEC	.XXX DEC	ANGLE
±.02	±.005	± 1/2°

MATERIAL

CONTRACT NO.	
APPROVALS	
DRAWN	
CHECKED	
ENGR	6/14/79
ITT	
OTHER	

ITT ELECTRO-OPTICAL PRODUCTS DIVISION
7635 PLANTATION ROAD
ROANOKE, VIRGINIA 24019

FIBER PULSE DISPERSION

MEASUREMENT AT 0.9 um

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	ECWG 212600
SCALE	REV. A	SHEET 1 of 7

SD-004 3 73 004-065

A.3-2

M 4

1.0 SCOPE:

The purpose of this measurement is to determine the pulse broadening of an optical fiber at an operating wavelength of 0.9 um. The pulse broadening, or dispersion, determines the information capacity of the fiber. This specification applies to 0.9 um dispersion measurements of both graded index and step index MMD fibers.

2.0 REFERENCE DOCUMENTS:

2.1 DOD-STD-1678 "Fiber Optics Test Methods and Instrumentation."

3.0 EQUIPMENT:

3.1 Electronic Equipment

Quantity	Description	Nomenclature for Diagram
2	Fluke 415B High Voltage Power	PS1, PS2
1	Heath SP-2730 High Current Power Supply	PS3
1	Lambda LL-903-OV Power Supply	PS4
1	RCA-SG2001 GaAs Laser and Driver	L
1	Stet CP1.4-17-10L Thermoelectric Cooler	TEC
1	Tektronix 7603 Oscilloscope Mainframe	SO
2	Tektronix 7S11 Sampling Units	
2	Tektronix S-4 or S-2 Sampling Head	
1	Tektronix 7T11 Time Base	
1	ITT Pocket Scope Image Intensifier	I.I.
1	Hewlett-Packard 8447D .1 to 1300 MHz Amplifier	A
1	Dispersion Pulse Controller or Berkeley Nucleonics Corporation 7075 Digital Delay Generator	DDG
1	RCA C30902E Avalanche Photodetector	APD
1	Hewlett-Packard 5082-4203 PIN Diode	PIN
1	Hewlett-Packard 7035B X-Y Recorder	X-Y

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SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RTVC 211600
SCALE	REVISION REV. A	SHEET 2 of 7

3.2 Optical Equipment

Quantity	Description	Nomenclature for Diagram
1	Set of lenses and microscope objectives	
1	3-Axis Micropositioner	
1	5-Axis Micropositioner	
1	Assorted Optical Rails and Stands	

3.3 Miscellaneous

1	Diamond Scribe RTJA 211586	
1	Vernier Caliper	

4.0 MATERIAL:

Description	Stock Room Number or Manufacturer
Razor Blades	026-008
Graph Paper	005-009
Masking Tape, 1.0"	016-008
TV Corona Dope	RT-VA-211585

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5.0 PROCEDURE:

5.1 Measurement Procedure

5.1.1 Place a new p o aph paper in the X-Y recorder and turn the recorder switch on. rn the chart switch to hold. Record the preform number and fi entification number of the test fiber.

5.1.2 Make a short end, leaving approximately 6.3 mm (.25") of bare fiber exposed, on the end of pull, marked EOP. Use the procedure of Specification RT-VJ-211,570 . Visual confirmation of room light reflection from the entire fiber end face is adequate to assure a suitable end. Clean the fiber end face with masking tape. Place the fiber in the 5-axis positioner so that the end is flush with the end of the groove.

5.1.3 Set control switch on the laser power supply, PS1 to "standby" position. Turn on the digital delay generator, DDG.

5.1.4 Set the sampling oscilloscope on left channel and to 10 ns per horizontal division.

5.1.5 Set the X100 knob on the digital delay generator at 1. Set the "REV" switch to the counterclockwise (reversed delay) position. This

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RTWJ 211600

SCALE	REVISION A	SHEET 3

5.1.5 (Cont.) retards the triggering pulse, allowing the operator to view the input pulse on the scope.

5.1.6 Set the laser power supply voltage, PS1, to 5 V above the threshold voltage specified for the laser in use, and turn control switch to "on" position.

5.1.7 Adjust the time position on the sampling oscilloscope until the trace of the laser pulse is at the far left hand side of the screen.

5.1.8 Make an end, leaving approximately 7.6 cm (3.0") of bare fiber exposed, on the start of pull of the fiber, marked SOP. Use the procedure of Specification RT-VJ-211,570 . Visual confirmation of room light reflection from the entire fiber end face is adequate to assure a suitable end.

5.1.9 Apply TV Corona Dope over approximately 5.1 cm (2.0") of the bare fiber, being careful not to contaminate the end. This will remove light propagating in the fiber cladding.

5.1.10 Clean dust particles from the end face by touching the end face to the sticky surface of a piece of masking tape. Place the fiber end in the 3-axis positioner so that the end face is flush with the end of the fixture groove.

5.1.11 Turn off room lights and view the end of the fiber with the image intensifier.

5.1.12 Maximize the intensity of the image by adjusting the 3-axis positioner.

5.1.13 Turn on the APD power supply, PS2. Set PS2 control switch to "standby" position. Place this 3-axis positioner in front of the A[illegible] train and against the stops. Check that PS2 is set to 20[illegible] [illegible] the voltage specified for the device in use. Turn PS2 control switch to "on" position.

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5.1.14 From the estimated length as supplied with the fiber, estimate the delay from the table on the wall of the laboratory. Set the controls on the DDG to the approximate delay. Adjust until the pulse is visible on the scope.

5.1.15 Adjust the 3-axis positioner for maximum intensity and record the delay (in nanoseconds) from the digital delay generator. Add 100 ns to the delay time. This is due to the internal preset delay of the dispersion pulse controller.

5.1.16 Adjust the 3-axis micropositioner to maximize the total area of the signal, as viewed on the sampling oscilloscope.

5.1.17 Spread the curve for best viewing by adjusting the timebase to the appropriate scale. Adjust the 3-axis positioner to maximize the area of the curve.

5.1.18 Adjust the laser power supply so that the laser is 1 volt above threshold.

SIZE	CODE IDENT NO.	DRAWING NO
A	13567	RTVJ 211600
SCALE	REVISION A	SHEET

5.1.19 Set the sampling oscilloscope scan on "manual."

5.1.20 Turn the switch of the X-Y recorder to the "SERVO" position. Adjust the trace controls on the sampling oscilloscope to fit the X-Y recorder, then turn the scan to the far left.

5.1.21 Set the pen down and turn the "PEN" switch to the "DOWN" position.

5.1.22 Adjust the scan control on the sampling oscilloscope to make one trace.

5.1.23 Lift the pen and return it to the left side with the scan control.

5.1.24 Reduce the laser voltage one volt and make a second scan.

5.1.25 Record the sweep range setting in ns/in. (1 oscilloscope div=1 in on X-Y recorder outputs)

5.1.26 Record the right channel voltage in mV/in.

5.1.27 Initial the sheet in upper right hand corner. Set both power supplies, PS1 and PS2, to standby position.

5.1.28 Turn off both power supplies, the digital delay generator and the sampling oscilloscope, if no further work is scheduled.

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5.2 Data Reduction Procedure

5.2.1 Referencing the graph obtained in the dispersion measurement, call the upper trace the laser trace and the lower trace the LED trace.

5.2.2 (Step Index Fibers Only) Draw a straight line between the end points of the LED trace, call this line the base line.

5.2.3 (Graded Index Fibers Only) With the Vernier calipers, find the maximum vertical separation ($i_y$max) between the laser trace and the LED trace.

5.2.4 (Step Index Fibers Only) With the Vernier calipers, find the maximum vertical separation ($i_y$max) between the laser trace and the baseline.

5.2.5 Calculate the vertical separation corresponding to the specified magnitude (% peak) multiplying the peak verticle separation, $i_y$max, by $\frac{\%\ \text{peak}}{100}$.

5.2.6 Set the calipers at the specified separation between the two curves.

5.2.7 Find the two points that have the same vertical separation between the curves as the new caliper setting and mark them.

5.2.8 Measure the horizontal distance between these two points. Multiply this number by the sweep range setting in nanoseconds. Record this number on the sheet. Call this number the output pulse width, W_o.

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5.2.9 Divide the delay, in microseconds, by 4.94 us/km and record this number as the length in kilometers.

5.2.10 Find the dispersion by using the formula

$$D_{(xx\%)} = \frac{1}{L} \times \sqrt{W_o^2 - W_1^2}$$

where L is the length of the fiber previously calculated in kilometers, W_o is the width in nanoseconds of the output pulse, xx is the magnitude percentage where the dispersion is measured, and W_1 is the input pulse width (provided). Record the dispersion in nanoseconds per kilometer on the sheet and on the attenuation sheet which accompanies the fiber.

6.0 <u>ACCEPT/REJECT</u>:

6.1 Not needed

7.0 <u>DELIVERY/STORAGE</u>:

7.1 Not needed

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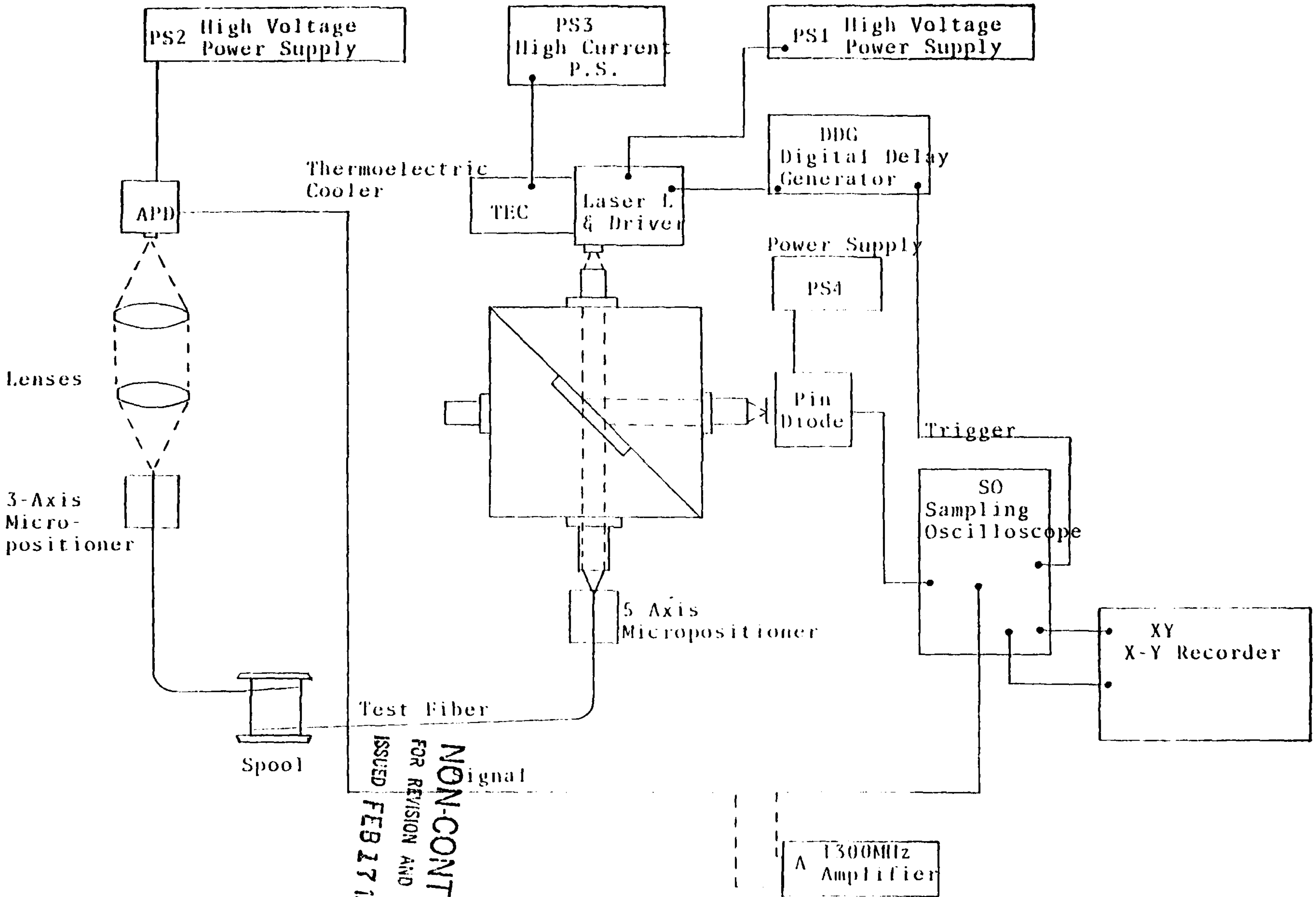

DISPERSION MEASUREMENT STATION

RT-VJ-211,600
Sheet 7 of 7 Rev. A

APPENDIX A.4

OPTICAL FIBER END PREPARATION PROCEDURE

INTERIM PROCEDURE

APPLICATION		REVISIONS			
NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APPROVED
	F.O.	A	SCO # 7294 KCD	4/23/79	
		B	SCO # 8125 JDM	4/3/80	

OPTICAL FIBER END

PREPARATION PROCEDURE

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SHEET SIZE																								
REV. LETTER																								
SHEET NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

.XX DEC	.XXX DEC	ANGLE
±.02	±.005	± 1/2°

MATERIAL

CONTRACT NO.

APPROVALS	
DRAWN	
CHECKED	
ENGR	
ITT	
OTHER	

ITT ELECTRO-OPTICAL PRODUCTS DIVISION
7635 PLANTATION ROAD
ROANOKE, VIRGINIA 24019

OPTICAL FIBER END
PREPARATION PROCEDURE

SIZE	CODE IDENT NO.	DRAWING NO.
A	13567	RT VJ 211,570

SCALE	B	SHEET

SD-004 3/73 004-065

A.4-2

M 9

1.0 SCOPE:

This specification details the procedure for the fiber end preparation technique known as the "Scribe-and-break" method. This technique is straightforward and allows rapid preparation of the high quality fiber ends required for fiber measurements. This technique can be used for any fiber fabricated with a glass core, including: CVD step, CVD graded, PCS, and single mode fibers.

2.0 REFERENCE DOCUMENTS:

DOD-STD-1678, "Fiber Optics Test Methods and Instrumentation."

3.0 EQUIPMENT:

Diamond cutting tool RT VA 211,586 with RT VA 211,595 refill or Majestic Tool per Exp. Dwg. #1074
Wire stripper (optional) - Jensen Tool # 4B 301

4.0 MATERIAL:

X-acto ® knife or razor blade 026,0088

Isopropyl alcohol 006,004-1

Freon TF Miller Stevenson II MS-190

Masking tape Stock # 016007

Paper tissue

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5.0 PROCEDURE:

5.1 Refer to Figure 1.

Tape fiber down to table approximately 12.7 cm (5.0 in) from the end.

5.2 Strip off plastic jacketing and buffer coating from 10.2 cm (4.0 in) of fiber.

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5.3 Remove remaining buffer particles by lightly rubbing a razor blade along the fiber, then rub the fiber between thumb and forefinger. Any remaining particles can be removed with tissue and isopropyl alcohol, as in Figure 2.

5.4 Refer to Figure 3. Grasp end of fiber with a small Piece of masking tape for grip.

5.5 Scribe fiber perpendicularly with diamond tool at point, providing length of bare fiber required in measurement specification.

5.6 Pull fiber end straight along axis and smoothly until break occurs.

5.7 Touch fiber end with a small piece of masking tape to remove residual glass particles.

5.8 Inspect end by observing a bright reflection from the fiber end. Inspection magnification is used where specified in the measurement specification.

6.0 <u>ACCEPT/REJECT CRITERIA</u>:

6.1 Any end which does not reflect well or shows unacceptable imperfections, should be reterminated per the procedure of paragraph 5.0.

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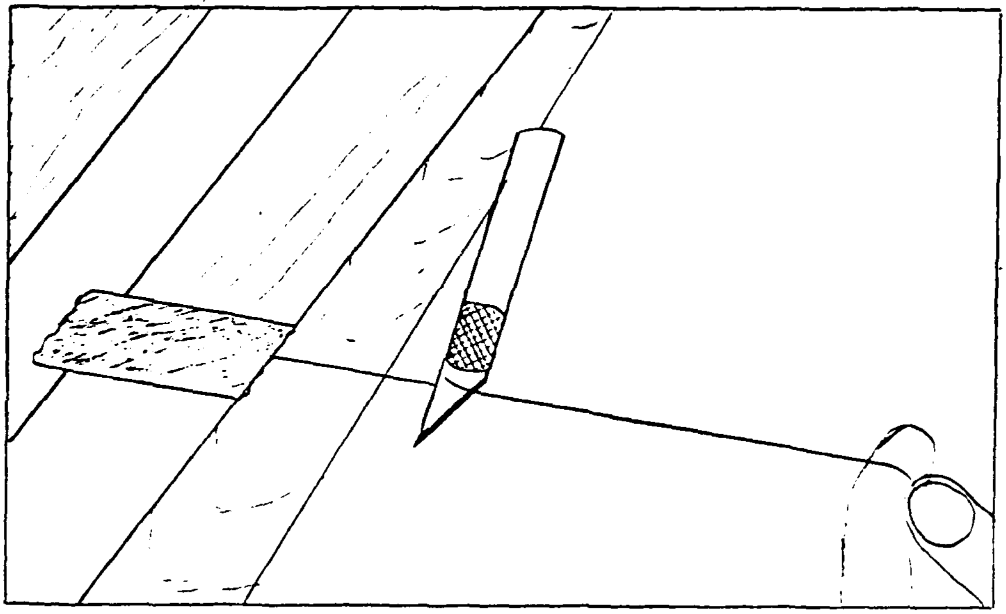

FIGURE 1

Removal of Plastic Jackets

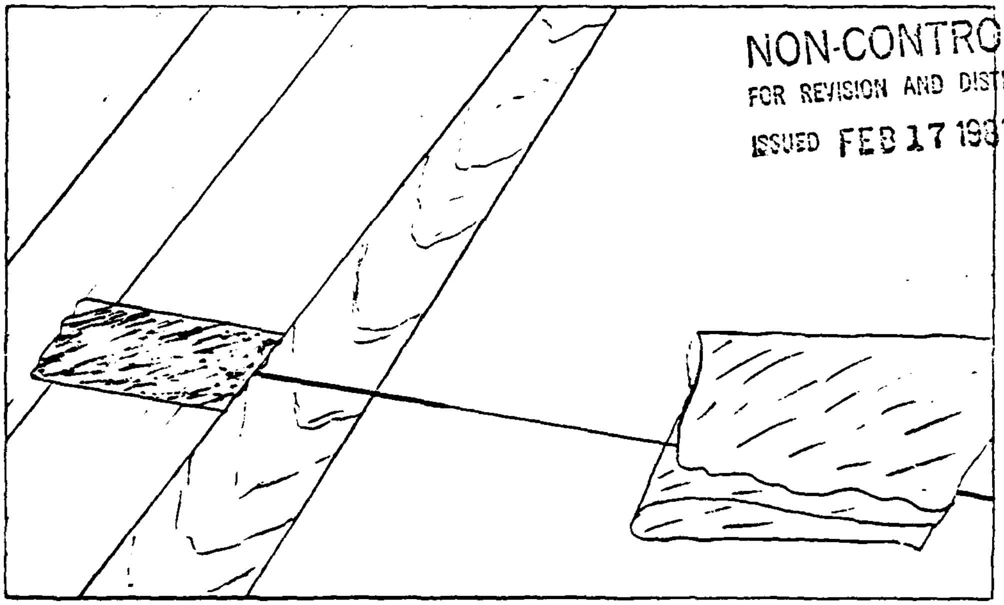

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FIGURE 2

Cleaning of Exposed Fiber

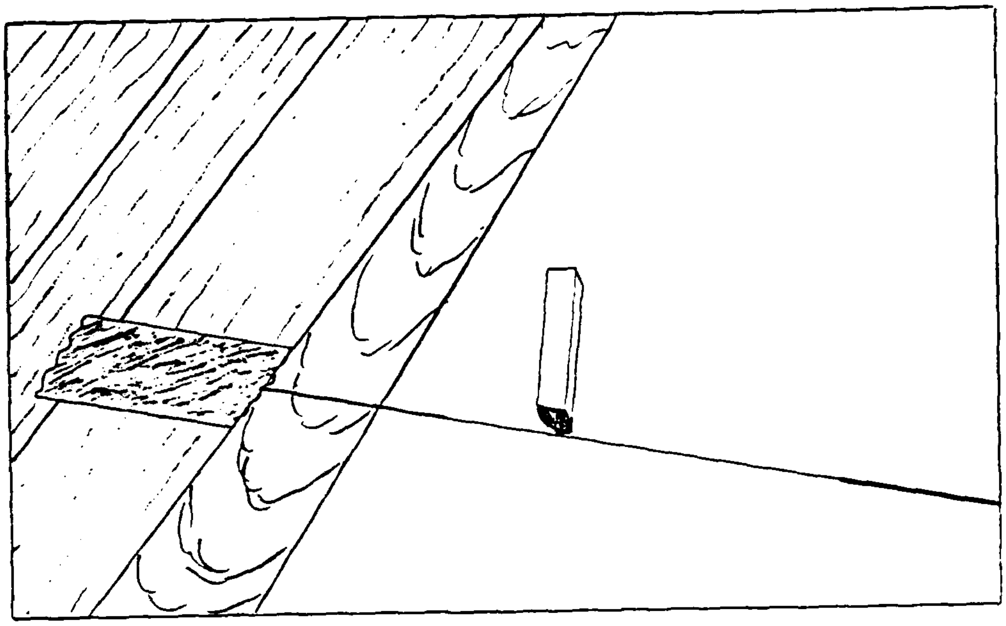

FIGURE 3

Use of Diamond Tool to Scribe Fiber

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APPENDIX B

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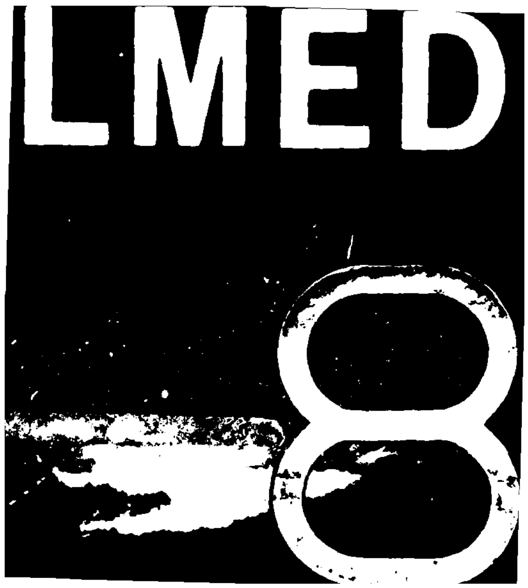
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